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THE DEVELOPMENT OF RESEARCH IN THE UNITED STATES

By James Rowland Angell
of the University of Chicago and the
National Research Council



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The Development of Research in the United States

By

JAMES ROWLAND ANGELL
of the University of Chicago and the
National Research Council

*An Address delivered before the Association of Land-Grant
Colleges at Chicago, November 13, 1919*

I. THE NATIONAL OBLIGATION TO FOSTER RESEARCH

Among the many lessons which the war taught us, few have made a deeper impression upon the public mind than that of the part played by science and technology in the prosecution of any of the great undertakings of modern life, and, for that matter, in the maintenance of the social order itself. That the United States has been backward in these directions was common knowledge to the experts, but was not suspected by the rank and file. In a general way it had long been a subject of comment that the Germans had succeeded in exploiting scientific research for the improvement of their industry and agriculture to a degree unrivalled by other countries. But with the outbreak of the war the crushing efficiency of the many new technical devices of the German army lent added emphasis of the most dramatic character to the appreciation of what had in that country been accomplished in these lines.

When the United States was drawn into the war one of the first problems which presented itself was the securing of the necessary number of scientific experts to organize and direct the tremendous technical enterprises which had promptly to be put on foot. Instantly, it became apparent that not only were we backward in the utilization of scientific methods and intelligence in the solution of our economic, social, agricultural and industrial problems, but also that we had no definite knowledge of where the personnel required to deal with the new scientific issues could be found. In other words, there had never been occasion for any general mobilization of our scientific resources, and we were accordingly obliged to start at the very beginning. One of the first tasks to which the National Research Council set its face was precisely this gathering together of competent men, bringing together the job and the man wherever possible. Most of these men were promptly swallowed up in one or another of the government organizations, chiefly those of the War and Navy Departments. But the lesson taught by this war-time experience will not be soon forgotten, and it is part of the peace-time program of the National Research Council to establish in perpetuity arrangements whereby there will be in some sense a permanent mobilization of the scientific ability of the country, to be directed in times of peace to the social, industrial and governmental necessities of such periods, and to be instantly available in case of a future war for the purposes of national defence.

While the war brought forth the most pressing demand for mere technicians in quantities never before dreamed of, and while the War Department struggled with a high degree of success to produce quickly the necessary number, and the necessary quality in these men, the more important lesson for our permanent interests in times of peace was the extent to which the demand was felt for men capable of carrying on research whether in the way of improving old methods, devices and apparatus, or in the way of devising wholly new methods. At the declaration of the armistice, practically every scientist possessed of any capacities for research found himself taken up in one way or another into the great national machine where he was called upon to make some contribution to the innumerable problems presented by the war. Nothing can be more certain than that the character and rapidity of our national development in all matters which relate to industry, agriculture, public health and the preservation of the physical framework of our civilization will be dependent upon the quantity and quality of sound research which is carried on. The truth of this assertion becomes even more apparent when one recognizes the fact that every modern nation stands in relations of industrial and commercial competition with other nations; and in the measure in which this is true, to fall notably behind the others in scientific development is to precipitate a trend of events which spells national depression and disaster. In other words, the price of a sound, progressive, national life is in these times widespread and intelligent scientific research.

It is to be recalled in this connection that Great Britain and her dominions, Italy, and Japan, have all set about to solve this problem through government subvention, and France is said to be contemplating a similar move. Now it is to be recognized with full appreciation that in recent years both Federal and State Governments have made substantial contributions for purposes of research, particularly in agriculture, engineering, and the industrial arts. The sum total of such appropriations for 1919-20 I have no means of giving with precision, but so far as I can discover, it runs up to at least \$10,000,000. All this is hopeful and indicative of an open-minded and progressive spirit. Such shortcomings as it exhibits are largely incidental to the administrative conceptions under which such legislation is sometimes carried out. There has perhaps been temptation to put undue emphasis upon immediate practical and local issues, some of them intrinsically trivial, rather than upon the more fundamental and far-reaching forms of inquiry; but it would be very unfair to criticize in any carping spirit a movement dictated by motives of so sound and generous a character, and one whose duration has been so brief as to afford relatively little opportunity for improvement through experience, the only means by which reliable knowledge can be gained. Certainly the national character of the obligation to foster research, both in pure and applied science, as widely as our resources will permit, cannot be called in question by any thoughtful observer of the present trend in the development of civilization, and it is essential in this connection that we conceive of research as the organized technique of science itself for its own propagation. It is, so to speak, the reproductive process of science. To think of it, as is often done, as a mere addendum to science, as a sort of luxury of the scientific idle rich, is fundamentally and perniciously false.

More specifically, this obligation to foster research means, first, the providing for a greatly enlarged personnel with much better fundamental training than is at present available. It means, second, the securing of the necessary facilities of laboratories, apparatus, and all the physical conveniences that are involved in scientific work. It means, third, the procuring of sufficient freedom from other duties to permit research workers to give their full and undivided attention throughout such periods as may be necessary to the completion of their research undertakings.

It may contribute to a just estimate of the problem which confronts us in this country to survey briefly the conspicuous characteristics of the major agencies available for the conduct of research.* These I take to be:

- (1) Experiment stations of the Federal and State Governments,
- (2) Federal scientific bureaus,
- (3) Research foundations including museums,
- (4) Industrial laboratories,
- (5) Educational institutions.

We may consider them in this order.

II. RESEARCH IN EXPERIMENT STATIONS

When the State and Federal Governments first established experiment stations which were, so far as I am aware, chiefly devoted at the outset to agricultural interests, there was great hope that they would become centers of the most far-reaching research. Many of them have indeed accomplished work of the very highest quality, but as time has gone on not a few—if I may trust report—have found themselves increasingly swamped with mere routine detail of a kind which represents, to be sure, a very real public service, but not one which is in any sense directly of a research character. Probably no one will question the desirability of circulating as widely as possible in a potato-raising district any new information regarding the best methods of combating the enterprising potato bug, but it may certainly be questioned whether it is a wise expenditure of the energy of a man competent to carry on fundamental research in entomology to permit his time to be monopolized by individual correspondence with farmers desiring enlightenment on the familiar pests of their own district. In other words, there has come to be some appreciable and unfortunate confusion of purposes, due in part to the very success of the experiment station, whereby its function as an essentially educational institution, disseminating useful knowledge, has come to be confused with its function as a device for investigation and the procurement of new knowledge. The issue is in some sense parallel with that in our universities where there is constantly in progress an active conflict between the obligations of instruction and those of research. The needs of each must be consulted, but neither must be allowed to stifle the other.

Moreover, with the growth of certain of our experiment stations there has arisen a lack of coordination between their several divisions which materially diminishes the value and the possibilities of their scientific output. Nowhere perhaps is the actual opportunity for scientific cooperation

*I am not unmindful of the many scientists, such as state geologists, health officers, etc., working under state auspices, nor of the unattached individual scientists in various parts of the country. But, I have intended to stress here simply the specific institutions in which research is of exclusive or considerable interest.

more obvious and yet—if again I may trust report—there is too often a practical isolation of the work of one division from that of another, with a resultant loss in the scientific productivity of the plant. Whether these difficulties, where they exist, are wholly remediable by a more thoughtful and effective organization at the head, or whether they are at present indigenous to the theory of the experiment station itself, I do not know. To an outsider, however, it would not seem an insoluble problem to hit upon devices which would assure frequent conference and intimate cooperation on the part of the personnel of the several divisions of such stations. That a station should be administered substantially as a scientific unit, if it is to achieve its maximal scientific productivity, would seem almost axiomatic. It is also reported that the stations conduct their work in too complete isolation from one another, and that profitable opportunities for cooperation are often neglected. If this be true, it should certainly be remedied as promptly as possible.

RESEARCH IN GOVERNMENT BUREAUS

The conditions in the scientific bureaus of the Federal Government are said to differ widely from department to department. Taken as a whole, the productivity of these groups has been most creditable, but again, just as in the case of the experiment stations, certain of them have been deluged with the obligations of routine detail connected with the dissemination of knowledge, with a consequent diminishment of their research productivity which has at times been most lamentable. Furthermore, as in the case of the experiment stations, assuming that current report may have some foundation in fact, there has in certain instances been not only absence of satisfactory cooperation as between the subdivisions of a given department, but there has also been a somewhat complete isolation of the bureaus of one department from those of another. I need not pause to describe the peculiar Washington conditions which have led to this regrettable result. I fancy I betray no secret, however, when I say that in general the traditional attitude of the several departments to one another has not been one of active cooperation. One need not be a wholly impractical idealist, nor totally oblivious to the fundamental interests of the departments as such, to regard this situation, so far as it is thus correctly described, as intrinsically unwholesome and probably unnecessary. It must certainly result in preventing to some extent the maximal research productivity of the federal bureaus. It is only fair to say that during the war conditions in this respect were markedly improved, and it may be hoped that with the resumption of peace-time conditions the lessons taught by the war may not be wholly forgotten.

The bureaus rightly enjoy, in some cases, splendid financial resources and an unrivaled prestige in the public confidence. On the other hand, it would be a piece of obstinate disregard of fact to overlook certain limitations under which their research work is carried on. For, once more, as in the case of the experiment stations, the bureaus are apt to be subjected from time to time to irresistible pressure to deal primarily with issues of apparently immediate practical consequence. It is proper and inevitable that a large part of their energy should be thus directed. Public support could hardly be otherwise commanded, and work of this character is urgent and essential. Now, it is well understood that as a byproduct of such

practical experimentation, scientific results of the most fundamental character are occasionally achieved. But, in general, it can be predicted with certainty that the great far-reaching contributions, running out in innumerable practical directions and valuable for generations to come, are the results of research in pure science carried on without any regard to immediate practical consequences. I would be furthest from implying that such research is not conducted in government bureaus. I merely remark that the almost inevitable tendency is in the other direction, and that in so far as this is true, the Nation fails to secure the largest possible returns from its scientific staff. Moreover, there are necessarily thrown about the expenditure of funds for government work certain arbitrary restrictions which arise again and again to hamper the efficiency of the scientific procedure. I will not say that these restrictions are inevitable under the conditions of congressional appropriation of funds, but I am reasonably certain that they are not likely to be wholly eliminated in any immediate future. From this point of view, private agencies, in many fields of work at least, enjoy a decided advantage.

RESEARCH FOUNDATIONS

I should include under this heading not only institutions such as the Rockefeller Institute and the Mellon Institute, but also certain of our great museums, which possess funds available from time to time for strictly research work.

These institutions, when effectively manned and intelligently administered, are extremely productive, both in fields of pure and of applied science. They are in a position to bring together groups of carefully selected experts, who can be surrounded with the best of laboratory facilities, and can be given complete freedom from every competing interest. The output of such institutions affords already convincing evidence of scientific achievements of the most valuable kind. There has been some disposition to urge that the great mass of the research work of the country should be carried on in institutes of this character. Despite their undoubted advantages in many directions, they are very costly to administer, and a good bit of their attractiveness and efficiency would be lost if they were compelled to operate under the conditions of state or federal stations, which is the only alternative when private resources fail. It is probably too early to judge with confidence regarding certain of their limitations, but there is some reason to think that there are relatively few men of the research type who work to best advantage in conditions of so considerable isolation as commonly exists in these institutes. The institutes are more or less specialized, and one of the great and impressive lessons which the war has taught us concerns the unexpected relationships which develop out of the pursuit of any of the larger scientific problems. A study which begins as a modest investigation of a zoological problem has presently run out into botany, physics, chemistry, meteorology, and goodness know what else. There are some advantages, therefore, for the fundamental research man, if he may find himself in a community containing a wide variety of scientific interests.

RESEARCH IN INDUSTRIAL LABORATORIES

This group is for the most part concerned in the very nature of the case with immediate practical issues, although some of the larger industries, particularly those dealing with electrical problems, have already discovered the potential value of research in pure science.

There is substantially no limit to the extent to which research in these organizations can be carried, for it is almost wholly a matter of organization and selection of a trained personnel. American industry has, as compared with German industry at least, and even with some portion of British industry, been astonishingly backward. As will be indicated at a later point, the National Research Council is making the development of research in the industries one of its principal fields of activity. Perhaps the most serious limitation in the administration of these research laboratories at present, apart from their dominant concern for immediate practical issues, is the extent to which in some organizations the individual scientist is kept out of contact with the work of his fellows in their attack upon difficulties of industrial or manufacturing procedure. Such isolation is at times demanded in the supposed interest of preserving trade secrets; at times it is a mere byproduct of the form in which the research work is organized. In either case, it tends to detract somewhat both from the interest and the dignity of the occupation, and, at least in the long run, to detract also from the rapidity of scientific advance. The attitude of mind generated in a scientist working in a laboratory of this type is necessarily somewhat hostile to that which has now become traditional in other fields of research. The obligation to give publicity to new discoveries in science is everywhere else held to be mandatory. Here the obligation is of a precisely opposite character, and the scientist is brought face to face with the antithesis between the supposed financial interests of his employer and the interests of his competitors and of the general public.

RESEARCH IN EDUCATIONAL INSTITUTIONS

The colleges, technical schools, and universities of the country sustain a double relation to the research enterprises of the Nation. On the one hand, in these institutions, and particularly the last named, there has been conducted throughout the last generation far the larger part of the research in pure science, with a very considerable representation of research in applied science in technical institutions and the professional departments of the universities. On the other hand, these institutions are at present the sole source from which is derived the trained personnel from which the remaining research agencies are recruited. In dealing with the problem of research in such institutions, this double function must be kept constantly in mind. Not only are we under obligation to safeguard and improve the conditions of research itself, but also, and in perhaps greater measure, to look to the conditions under which the highest class of research men can be produced. Both quantity and quality must be improved.

It is a matter of common knowledge that the most serious limitation of the research productivity of these institutions is occasioned by the overwhelming burden of classroom instruction which many of the men are obliged to carry. Such classroom work is not only destructive to research because of the sheer intellectual and physical fatigue which it occasions,

but also, and perhaps more significantly, because of the interruption to attention and the close observation of critical phenomena which it compels. In some fortunate institutions provision has been made for considerable periods of uninterrupted research work, and again, in certain other institutions men can so arrange their teaching duties as to secure freedom in certain portions of each week. But, in general, university research is carried on in the interstices of other duties, and the only wonder is that so much of it is produced, and that on the whole it is of so respectable a character.

Again, many institutions in this group are seriously limited in the physical facilities which they are able to put at the disposal of their men. Much admirable research has thus been crippled at the very outset.

In the training of personnel the same difficulties recur, with the added difficulty, now much aggravated by the prodigious increase in the cost of life, that the research career is even less attractive than in the immediate past. The Nation must be aroused to a full appreciation of all that this implies in the decadence of our position in the scientific and industrial world. So far from being in a position successfully to survive a decrease in this personnel, we need a very great increase in the number and a great advance in the quality of the men entering upon this career. The answer is obvious, even simple i. e., salaries for research men must be very materially increased, the conditions of work must be made intrinsically far more attractive and, if possible, there must be secured a larger and more intelligent public appreciation of the social contribution made by the successful investigator.

One serious shortcoming of the research functions of educational institutions as at present administered is the substantially complete lack of any rational program for dividing among themselves the field of research. Many institutions have as a consequence of this fact been tempted into the effort to develop research in many lines of work which they ought never to have undertaken. State institutions in particular are often exposed to pressure, which they find it difficult to resist, to set up new departments, many of them implying research as part of their work, where such departments are in no educational sense at all justified. There must certainly be a careful study of this situation with at least informal cooperation among the universities, if we are in any degree to reap the largest harvest from our research possibilities. To multiply indefinitely the same type of research work in an unlimited number of institutions condemns us at once to a most wasteful expenditure, both for material and personnel, with no possible corresponding advantage.

This sketch of the research facilities of the country makes no pretense of being exhaustive, but it may at least serve to indicate the major groups of agencies, and something of the peculiar circumstances under which research is conducted in each of them. My purpose has been to suggest the very varied conditions which exist in order to make clear that any fundamental program directed to the improvement of our national efficiency in all this matter must take constant account of the complexity of the problem and provide for such methods as the exigencies of each group may require.

III. ORGANIZATION AND COOPERATION IN RESEARCH^{*}

It is a not infrequent remark, and one which I believe to be measurably just, that science despite its magnification of method has never seriously worked out the method of its own organization. For the most part, it has thus far rested on individual initiative and on such loose forms of cooperation as are based upon the magnetic or coercive personality of some one scientific man. Assuredly, nobody expects to achieve a system of scientific progress which will in any sense be independent of the presence of commanding intellects; but it is equally certain that scientific men have as yet only achieved the most elementary beginnings of the organization of scientific interests. Indeed, it has been something of a fetish among scientists that we must rely upon individual inspiration and initiative, and that the individual worker must be safeguarded in every possible way from the corroding influence of administrative organization. It has unfortunately been generally assumed that an organization which interests itself in research will inevitably exercise such a depressive influence on the research worker. This I believe to be essentially untrue in theory, and I am at the moment connected with an organization which is directing all its energies to proving it untrue in fact. No doubt there will always be wide ranges of scientific work where the individual must toil more or less alone, but on the other hand, no one who has thoughtfully contemplated the conditions under which modern science does its work can have failed to be impressed with the innumerable unimproved opportunities for cooperation.

In the first place, we have, through processes which I need not stop to describe, parceled out the field of knowledge to a great group of sciences each of which is, perhaps not unnaturally, disposed to claim supreme jurisdiction over its own bit of territory. The world of science has thus come to present somewhat the appearance of an English landscape with its checker-board effect of small fields set off from one another by high, impenetrable hedges. To one who toils inside such a field, the universe is limited by his own hedge-row, and inside it he desires to be left in peace to cultivate his crop as best may suit him. The parable has of course its element of exaggeration, but it is unfortunately not so much exaggerated as one might wish, and there are not a few scientists whose thought and speech would seem to indicate an amazing lack of appreciation of the intellectual context of their own work.

The actual fact, of course, is that the dividing lines of science are, like the hedge-row, in large measure arbitrary and practical, and consequently subject to persistent modification. Practically speaking, chemistry and physics are profitably conducted as separate sciences, and yet they overlap and impinge upon one another in ways which have already created the border science of physical chemistry. Botany and zoology have similar relationships. Chemistry and physiology are neighbors of the most intimate kind. Psychology and neurology can hardly get along the one without the other. And so it goes. Now under the present organization of science—or lack of it—there is no localized responsibility for bringing together in co-operative enterprises research workers occupying fields that are thus convergent or overlapping. There is genuine need for such cooperative work

^{*}The subjects discussed in the remaining sections of this paper were touched upon in similar form in an address before the Association of American Universities at the meeting held November 7, 1919, at Columbus, Ohio.

in many different directions and one of the first obligations of any method adopted to further the general interests of scientific research must be the providing for investigations which shall thus bring together the scientists now occupying neighboring but distinct fields.

Obviously organization in research must involve something substantially different from organization in enterprises of other kinds, for example, war, industry, sport, and exploration. Organization, I take it, looks primarily to the efficient mustering of all the resources available for a given undertaking, and as the ends desired vary, so do the means for their attainment. In war, the individuality of the private soldier must be in large measure subordinated to the conception of the high command, and while any ideas he may have to offer may theoretically be received, in practice his initiative is reduced close to the zero point through the larger part of his service. Obedience, rather than initiative, is the first military virtue. Similarly in industry, ideas are desired and generally encouraged, but nevertheless in the stress of the day's work, each individual workman must play his previously assigned part, play it promptly and without debate, become in short a cog in the great machine; otherwise production is blocked and economic disaster may be the result. Initiative and ingenuity are essential at the top of the organization. Moreover, ideas supplied from workers at any level of the process are in progressive industries welcome, but the actual application of them to the procedure in hand must ordinarily come from above and the individual unit in the machine must function more or less mechanically.

Evidently organization in research calls for quite a different distribution of effort. Individual initiative, resourcefulness, ingenuity, imagination, vision, must be kept at a high pitch all along the line. Here we are not concerned with quantity production of a stereotyped product, of which the hundred-thousandth specimen shall exactly resemble the first. On the contrary, the product is in some sense constantly varied and unless it prove to be varied, the process has failed of its purpose, has degenerated into mere hack work, or has been based on essentially mistaken principles. On the other hand, the conception not infrequently entertained that the research man is necessarily the genius working in seclusion is essentially untrue to most of the facts. Many a genius works in seclusion and all research men must be free to work undisturbed at the task in hand; but there are many forms of scientific problems whose solution is essential to the modern world, which are so complex that no one scientist is equipped to deal with them single-handed. Either they must wait for their solution upon the accidental arousal of interest in the appropriate group, or there must be some definite purposeful cooperation established. The great fundamental discoveries may perhaps, as a rule, await the wholly spontaneous efforts of the great genius, but many discoveries of the utmost value to humanity have come from the somewhat accidental observations of men of essentially moderate talents. And not only so, but a very large fraction of the progress in our scientific knowledge in the last 50 years has come not from the work of the occasional genius, but from the hard, persistent, thoughtful investigations of men who would never be classed as geniuses in any ordinary sense, but rather as trained men of large native ability. This group of men are more often than not, eager for those forms of contact with other scientific workers which shall enlarge their own outlook upon the problems with which

they are engaged and which shall enable them to pursue more effectively their individual researches. For such men betterment of the machinery of scientific cooperation and the dissemination of useful scientific information involves not only no invasion of their individual initiative, but often is the condition of its successful expression.

To put it in slightly different form, and at the risk of repetition, one may say that a fairly prevalent conception of research associates it with the somewhat mystical intellectual operations of the genius, or "near-genius," to tamper with which is a kind of profanation. In this view one must simply wait upon the deliverances of fate. To attempt to assist by any devices of organization is futile. As a matter of fact, large areas of the most needed research lie in territory where properly trained men of talent, given proper conditions of work, may produce constantly and in increasing measure results of the utmost consequence. But one of the conditions of maximal efficiency is that they shall work inside the framework of a general program in which there is intelligent cooperation in the allocation of the field and in the constant communication of results achieved. Such distribution of responsibility and effort is entirely consonant with the fullest actual initiative which any scientist can desire. No one compels him to investigate where he does not desire so to do, but by a centralized device for planning, he can make his effort count for far more than when he works wholly alone. This is as true of the zones of pure science as it is of the regions of applied science where organization is often thought of as less foreign to the ends sought. Indeed in the research laboratories of a few of the great industries such cooperation has produced the most remarkable results.

Even if organization in research meant no more than thoughtful discussion and planning among a group of men engaged in the same lines of work, it would be immensely worth while. For example, here are a dozen forestry experts in position to determine the research problems which shall be first attacked by the staffs of a dozen different organizations. If there be no contact among them, they may all decide to start upon exactly the same problem, or upon utterly disconnected problems. Undoubtedly, some excellent results may emerge under such conditions. And yet nothing is more certain than that the energies of the entire company could have been invested to far better purpose with much less of wasted effort had there been intelligent planning before work began. There is abundant practical experience to justify this conclusion. Repeatedly it has occurred that men working in entire ignorance of what others in their field were doing have traversed the same ground and with results which in no wise justified the wasted effort.

But as a matter of fact, organization in research means much more than this. Many highly important projects, as we have observed before, involve for their execution the converging efforts of men in different fields of science, and in applied science in particular. The agencies interested in improvement of methods must at times come together to set in motion the necessary research work, or it will not get done. Furthermore, the technique for the prompt and convenient dissemination of information regarding discoveries in research is at present lamentably imperfect, and we shall never capitalize our scientific energies at anything like their full value until this condition is removed.

Cooperation in research may be profitably developed, first, as between scientists working upon related problems in the same general field—say physics; second, as between scientists in different but adjacent fields—e. g., chemistry and biology; third, as between scientists in different countries, where such cooperation is often essential to success; fourth, as between agencies like the industries requiring the benefits of research; fifth, as between organizations, e. g., government bureaus, experiment stations, and universities; and sixth, by improvements in methods of rendering easily accessible information regarding scientific discoveries.

As practical illustrations of the type of thing we have in mind may be mentioned certain of the problems of public health; for example, sewage disposal presents a question in which the organic chemist, the colloid chemist, and the sanitary engineer are all necessarily involved. The National Research Council has secured the services of a very representative committee to study the fundamental problems of food and nutrition, a problem which in this same way represents the combined interests of a considerable group of sciences. The successful solution of the problem cannot be reached without the cooperation of men representing these distinct but related fields of science. One of the most promising ranges of contemporary research is in that borderline group of problems in which the biologist, the chemist, and the medical scientist find their interests converging. A physiological chemist, however learned he may be, is compelled to turn from time to time for scientific assistance to one or other specialist in this group of neighboring sciences. Indeed, it is practically impossible to pitch upon any problem in modern life whose complete solution does not involve an appeal to several lines of scientific approach. In certain cases, through more or less happy accident, the required scientific cooperation is easily secured, but in many instances there has been no adequate provision for securing such combined attack.

Again, within the field of any one of the great sciences, there is opportunity for a kind of cooperation in research which has never been undertaken on any large scale and which can, if properly stimulated and guided, produce results of the highest consequence. For example, there is at the present moment being considered by the National Research Council a nation-wide investigation of the problem of reforestation such as no extant single agency can hopefully attack. Similarly, it is hoped to study the problems of soil fertilizers in different regions of the country by means of cooperative effort in a considerable group of appropriate agencies.

In certain ranges of science there is not only necessity for the cooperation of individual scientists, working on different aspects of the same central problem, but here is also need for international cooperation. One only needs to cite such problems as those of astronomy, seismology, meteorology, and terrestrial magnetism to appreciate how essential simultaneous observations at various points of the earth's surface may be. In such cases, international cooperation is absolutely indispensable. Nor are the forms of profitable international scientific cooperation in research confined to the spheres of astronomy and the major phenomena of the behavior of the earth's surface. The study of the behavior of plants and animals under certain standard conditions will afford numerous instances in point.

Perhaps the most obvious illustrations of the possibilities of successful cooperative investigation are represented in certain forms of industrial

research where a group of producers come together and establish a research organization, either establishing laboratories of their own for this purpose, or utilizing extant laboratories through which they can arrange for the admittance of their investigators. It is of course well understood that certain of the great manufacturing industries, particularly those connected with the development of electricity, have developed laboratories of the most elaborate kind and of a very high degree of efficiency. But the smaller concern cannot afford to develop its own scientific staff, and consequently the cooperative device is found to be the best substitute. This process, which has been carried to a considerable development in Great Britain, is being rapidly fostered in this country and gives promise of extremely valuable results. Several different methods of procedure are feasible, but time will not permit further discussion of the matter here.

Finally, one may mention the types of cooperation in research which may be achieved by the establishment of more intimate contact between the organizations and institutions now actually engaged in such work. As has been already indicated, we have at present, as the main features of our national research equipment, certain of the scientific bureaus of the Federal Government and the several States, certain large research foundations, including a few of the great museums, a group of research enterprises in the industries, and the research work done in our universities. In each of these, individuals are at work on problems which, so far as is known to the men engaged upon them, are at the moment not under attack elsewhere. But our present organization is totally devoid of any adequate means for securing information as to the research work at a given time in progress. In consequence, it repeatedly happens that men are found to have been working on common problems, investing time and energy which might have been expended to far better effect could they have been brought in touch with one another and have learned each what the other had to give in the way of knowledge already ascertained. In the case of the industrial laboratory, both the economics and the ethics of the case render it improper that information should be disseminated as to what is being learned. Even scientific men working alone as individuals have oftentimes been extremely jealous of their prerogatives in the matter of priority of scientific discovery, and have treated their work somewhat in the spirit of the trade secret of the industries. But over against this relatively small group there has always been a larger and more open-minded body of scientists eager to learn whatever could be brought to bear upon their own researches, and willing and ready to communicate to others whatever they had to offer of worth. Generally speaking, the ethics of scientific research outside the industrial laboratory is rapidly coming to a point which commends and demands publicity. Indeed, it may be said that this condition has already substantially arrived. Men are eager for more prompt and adequate means of publication of scientific work, and one of the crying defects in the scientific situation as a whole, one which is far more serious in some branches of science than in others, is the need, first, for a central clearing house of information regarding current research work and its status from month to month and year to year; and second, far more complete and more effective modes of publication of scientific results. Publication needs to be more prompt, and needs to be accompanied by much more adequate methods of abstracting and indexing than at present are in operation. To these

problems, also, the National Research Council, through its Division of Research Information, is turning its hand, and we hope to be able not only to point the way to better conditions, but also to make a substantial beginning in the actual improvement of these conditions. I will not pause to discuss the entire program of this service, but I may simply say in passing that it contemplates catalogues of research laboratories, of current investigations, sources of information, laboratory facilities, catalogues of scientific and technical societies with indices of foreign reports, and a somewhat detailed program for the improvement of scientific publications, with particular regard to systems of abstracting and indexing.

IV. ORGANIZATION OF NATIONAL RESEARCH COUNCIL

To assist in meeting some of the needs of scientific organization in the United States, the National Research Council has been organized. It attempts to achieve in a democracy, and by democratic methods, such a mobilization of the scientific resources of the country as shall permit their most effective use not only in times of crisis such as war, but also continuously in times of peace. The German Government had succeeded under autocratic methods in carrying such organization to a high degree of perfection and had procured the most striking results not only in the military administration, but also throughout the entire field of industry. Whether we shall be equally successful under the voluntary extra-governmental plan which we are developing remains to be seen. It may, however, be said at the outset that, rightly or wrongly, the opinion of scientific men is substantially unanimous that in our country an enterprise of this character can only reach its highest possibilities when freed from the restraint of government control. This, however, should in no wise be understood as reflecting upon the efficiency of the scientific work carried on by the various departments of the Government. It does, however, argue a widespread conviction based on experience that these departments, despite their many great advantages, must of necessity work under limitations of a very definite and often unfortunate kind.

As the first step in securing a democratic foundation, the National Research Council is based upon the election of members by the great scientific societies of the Nation, some 40 being represented in the present roster with a constituent personnel running up into the thousands. These representatives from the scientific societies are organized in divisions, of which there are seven representing science and technology. Each such division elects a chairman, who becomes a salaried officer of the Council, resident in Washington for one year, and in charge, together with an executive committee of his division, of the scientific work to which the division decides to set its hand. Provision is made for a certain number of members of each division to be selected at large, thereby insuring as far as possible the presence of a thoroughly representative scientific group, for it may at times happen that some important scientific interest is by accident omitted in the elections from the societies.

The Council has also six so-called general divisions whose officials are appointed by the executive board of the Council, and who conduct the work of the divisions much as in the case of the science and technology group. The personnel of these divisions is determined by the executive board, with the exception of a few persons who are *ex officio* members.

These divisions cover the Federal Government, foreign relations, the states relations, education, industrial relations, and research information.

The government division has upon it representatives of each of the scientific bureaus of the Government, and is intended to foster, so far as possible, cooperation among such bureaus and among the outside scientific agencies working on similar problems.

The foreign relations division has to do with foreign scientific societies. An International Research Council was established at Brussels during the past summer, and will take the place of the old international associations and unions which, in forms somewhat modified by the war, will comprise the international unions organized under the International Research Council.

The states relations division concerns itself with the attempt to foster helpful cooperative relations among the scientific bureaus and other scientific organizations of the several States. There appears to be opportunity here for an outside disinterested agency to render very great assistance.

The educational division has to do with the interests of research in educational institutions in all its aspects. This division is beginning its work by a careful study of the actual facilities for research in our American educational institutions. It is hoped that by bringing together reliable information about these conditions it may be possible to formulate a more effective program for the utilization of such resources as we now enjoy, for the improvement of the same and for the development of a larger number of better trained research men. Any rational adjustment of the program of research development in our universities, such as was referred to earlier in this paper, involves a careful preliminary scrutiny of the extant situation. There are some types of research work whose development can be justified only at a limited number of institutions. To have a great group of universities each attempting to do such work is wasteful of personnel and material resources alike. We shall hardly, however, be able to move on to a saner distribution of scientific effort until we know more precisely what are the actual facts in the case, much less can we educate public opinion to accept a reasonable distribution of responsibility.

The industrial research division has as its work the stimulation of research in the industries. It seeks particularly to bring into contact industrial groups, interested in improving their scientific technique with scientific men and agencies competent to render the necessary assistance.

The research information service involves a program in many ways the most unique which the Council has to offer, in its attempt to create mechanisms for giving prompt and accurate information regarding not only the finished products of research of all kinds and in all parts of the world, but also the conditions in current research. Its general intentions have already been briefly described and need not be repeated.

Taken in its entirety the work of the Council is to be understood as primarily one of stimulation of research in both pure and applied science, and in the creation of an enlarged and better trained research personnel, with particular emphasis upon the securing of cooperation wherever this can be profitably accomplished—cooperation as described above among scientists in the same field working on different aspects of a common problem, cooperation among scientists in different fields, whether at home or abroad, studying a group of related problems, cooperation among research or-

ganizations, and, finally, cooperation among agencies which require the services of research men and research organizations.

The Council is itself frankly a piece of research, a great experiment, whose outcome we await with undisguised interest. Its purposes are worthy beyond question. If its methods be unsound, better ones must and will be devised. Meantime it invites your sympathetic support and offers you whatever service it can render.

THE PRESIDENT. The discussion of this important topic will be opened by Dean R. W. Thatcher of the University of Minnesota.

R. W. THATCHER. I am interested in the statements made by both Dr. Jordan and Dr. Angell to the effect that there is great need for the development of personnel with a view of promoting research. The subsidizing of prospective research workers is an important matter and likewise the responsibility of those subsidized. There are plenty of good arguments in favor of subsidizing young men through scholarships, fellowships, etc., in order that they may prepare themselves for research work; but sometimes such young men consider themselves objects of charity, sometimes, on the contrary, they are more mindful of their own assumed rights than of those of the institution that deals with them. Perhaps we carry philanthropy too far; sometimes it is better to allow young men to prepare themselves for research work at their own proper expense.

Dr. Angell has presented a critical review of the agencies for the promotion of research work and the development of personnel. I have planned to discuss the means by which additional public support for research, particularly agricultural research, can be secured. I am not sure whether this covers a phase of the problem which the Executive Committee had in mind when they selected this topic for discussion at this meeting. I suppose that the question of possible resuscitation of research might be supposed to mean that research is in a dying or comatose condition. I have not felt that such was the case. It has seemed to me that the experiences of the war have led to a new appreciation of the value of research work and that there never was a time when there was so insistent and so consistent a demand for thorough research as at the present time. I suppose it is fair then to raise the question, whether this war-time public interest in and appreciation of the value of research has waned or whether this question is merely one of how to capitalize the present interest in this work into a policy which shall work out in permanent good. I suspect that there is the fear at least that public interest is or will be waning and that public support is going to be hard to obtain. For that reason, I have chosen to discuss this phase of the problem and assume that a brief discussion of certain fundamental facts in the present situation as it appears to me will not be out of order.

As I see it, there are three distinct types of forces which have exerted in the past and are exerting at present pronounced influence is stimulating interest in and providing funds for the support of research. These are, respectively, industrial or economic necessity, personal or corporate philanthropy and educational policy. As specific effects of these three types of influence, I may mention, first, the research which is being carried on in connection with the regular work of manufacturing enterprises, factories, smelters, etc.; second, that which is supported and endowed by cor-

porations like the Rockefeller Institute, etc.; and third, the publicly supported research work which is a part of every important educational institution of high standards and standing, and of various state and governmental institutions which help to establish the educational system of the country.

The character of the research work which is undertaken, as well as its general effect upon the public mind and public good, are significantly affected by the purpose for which it is established.

The first type is characterized by having a specific end or object in view, seeking to establish facts of technical importance and with probable definite and profitable application in industrial processes. Its results are generally protected by patents insuring use only by the private agency which supports the investigation. The public learns of its results only indirectly and has no direct interest in the facts which are demonstrated or in the methods used in researches.

The second type is an outgrowth of the experience by industrial agencies of the benefits of technical research, and is an attempt to provide similar skilled investigations of subjects of broad public interest, using funds which have accrued from the results of the application of scientific methods, business acumen, or exploitation of the natural resources of the country, for the establishment of facts of public, economic or humanitarian interest. The results of these investigations are open to public use, but up to the present, at least, this work is looked upon by a large proportion of our people as having back of it some secret or sinister motive, or else as an attempt to win support to corporation interests by activity in a field of public service which is too technical in character for the public mind to grasp. I am not belittling this work or criticizing the motives of these great endowments for scientific research, but am attempting to present what seems to me to be the public reaction toward them.

The third type of research work has always been a part of the activity of educational institutions. Everyone recognizes the necessity for constantly enlarging the borders of the field of human knowledge. Teaching without research soon becomes hide-bound, uninteresting, of little inspirational or cultural value. But the atmosphere of the university, in the past at least, has tended to limit the field of research to those problems which were academic rather than technical in importance. "Truth for truth's sake" is a familiar slogan. Undoubtedly this is an inspiring motive for research men, but it has not appealed to the public imagination. Hence, public support for this work has sometimes been hard to get, because of the idea, false though it may be, that the work is "impractical," "theoretical," or "visionary" in character. Please understand that I am not defending this point of view. No one has keener respect for the methods and results of this type of research than I. Furthermore, much of the very best and most fundamental research in science can be shown to have direct economic value in industry or agriculture. But the results of this type of research, while freely available to the public, seem to be regarded as of little use to it. I believe that it is a correct interpretation of the general public reaction toward it to say that its purpose, methods, and results are little understood, and there is little enthusiastic support for it. The work of the agricultural experiment stations is somewhat better known and enjoys a somewhat more desirable position in the public mind than does general

university research; but even here it is evident that station men feel that they do not have all the public support to which the importance and value of their work should entitle them.

As a result of these conditions, I had come to the conclusion, prior to the outbreak of the World War, that support for research work was tending toward concentration in the hands of private enterprises, with private and personal control of both the methods and the results of the investigations. This seemed to me to be extremely unfortunate. I felt that the general public good demanded that the very best that educated scientific skill could contribute to the solution of the problems of public business, of public health, of public food supplies, and of public social and moral development, ought to be freely available to the use of all rather than confined by patents or other means of maintaining secrecy to the individual profit of a single corporation or industry.

Then the war came on, with its insistent demand for new methods of meeting every conceivable type of constructive and destructive processes. It seemed that success in the war was to go to that nation which could outfit the other in the production of new engines of war, new uses of poisonous gases, new sources of supply of foodstuffs and munitions of war, etc.,. It became almost a trite saying that the war is teaching the world the value of research work.

Now the war is over. We are faced with the problem of securing more public interest in and support for research work, the results of which shall be available for the general public good. I suppose that there was in the minds of the committee which suggested this topic for discussion, the idea that during the war active work on agricultural research has been interrupted by the necessities of the war, and that it is of importance now to restore it to prewar activity. I have not felt this as a critical condition. It has seemed to me that the increased appreciation of the practical value of research work of all kinds, including agricultural research, has more than counterbalanced the disrupting influence of the absence of our men in war time service. Further, many of our men have come back with increased respect for research work as a result of their participation in the work of the sanitary corps, the hospital corps, the engineering corps, etc. and their insight into the work of the research organizations in this country and abroad. Therefore, I believe that the present problem is not so much one of getting new interest in research as a life work or better institutional conception of the values of research to the institution as it is that of arousing general public interest in and support of this kind of work.

I believe that the first step is to encourage those who are influential in forming public opinion through addresses, papers, etc., to present this matter in its true light wherever the opportunity is offered. In so far as it concerns agricultural research, this duty will fall on those of us who represent the land-grant college movement, as a whole.

In this campaign, I think that the first fact to be emphasized is that research is not teaching. Agricultural experiment stations have usually been located at or in connection with agricultural colleges. This has given rise to the idea that the experimental plots, feeding stalls, laboratories, etc., are intended to teach or to demonstrate certain established facts and much of the criticism which has been directed toward experiment station work has been due to this misconception. Next, I think that the necessity for and

value of exact measurement of all of the contributing factors in an experimental investigation should be explained as ample reason for the expense of such operations as compared with that of similar operations in established enterprises. Such careful work distinguishes real investigation from the haphazard trials or experiments which constitute a part of many ordinary farm operations. Then we must point out that skilled scientists (not necessarily trained farmers) must be used in these investigations; and that agricultural operations like industrial operations are founded on true scientific principles, and that only those who are trained to recognize and understand these principles can accurately interpret the observations which are made in the field or laboratory and draw the correct conclusions therefrom. We must not fail to emphasize the fact that as soon as an experimental study has been brought to a definite conclusion its practical application to agricultural operations will be demonstrated through the extension agencies provided for that purpose. However, it is a sad mistake so to emphasize the practical or economic importance of agricultural research work that our constituency gets the idea that only men of practical farm experience should be used in agricultural investigational work.

I feel that I would not be completing this discussion of the steps which I think lead toward the securing of public approval and support for agricultural research work, if I did not allude here to the phase of the matter which I have already discussed at a meeting of the section on experiment station work, namely, the necessity for the presentation to the general public of such a united front and such a spirit of cooperation and sympathy between research workers as will lead to more general public confidence in the accuracy and the impartiality of station research work. Dr. Angell has emphasized the need for cooperation between research agencies. I feel that this point can not be overemphasized. As a result, in part at least, of the habit of public criticism of each other's work, which may be a perfectly proper and legitimate incentive to scientific accuracy, the general public has become accustomed to belittling the opinions and the work of so-called "experts." It has become skeptical of the possibility of securing disinterested, impartial and accurate scientific evidence on any question of public concern. On these accounts we need to do everything within our power to re-establish public confidence in expert opinion and to emphasize the true reason for our work, namely, the contribution to the public welfare of an accurate, impartial and thoroughly scientific basis for educational, industrial and agricultural development.

Finally, I should say that the missionary in this movement for better understanding of agricultural research work should be full of a message of good cheer. Pessimism and discouragement never are efficient aids to any movement. Fortunately, there is nothing in the present situation which ought to create this discouraged feeling in the minds of our station men.

Out of the chaos of conflicting political opinion and of rising class prejudice, our efforts to extend the borders of human knowledge, to enlarge the safe and sure foundation for agricultural development, to sift the wheat of true knowledge of nature's laws out of the mass of chaff of superstitious beliefs and misinterpreted results of individual farm experiences, stand clear of suspicion of class interest or improper motives. We may take tremendous satisfaction in the thought that we are dealing with permanent verities rather than with passing vagaries and impulses. Being

optimistic and courageous ourselves, we may approach the task of securing public confidence in and support for our agricultural research work with every assurance of success.

THE PRESIDENT. May we hear from President A. F. Woods of the Maryland State College?

A. F. Woods. It is really quite unnecessary for me to continue this discussion. I was put on the program as alternate in case Dean Thatcher was not here. Certainly there is no disagreement among the stations and colleges on the questions laid before us. We all understand the purposes of the National Research Council. We realize that the Council is doing everything in its power to promote research and to develop a public sentiment that will support it. I do not believe that we shall find serious difficulty in maintaining our national and state supported research agencies. The support of the National Research Council will undoubtedly be available in maintaining this interest in publicly supported research. I am glad to note the interest of this Association in cooperating with the National Research Council. In my opinion, the organization of the Research Council is one of the great forward steps in the development of a national policy looking toward the coordination of fundamental research.





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